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EFFECTS OF CONTINUOUS SELECTION FOR EAR TYPE IN CORN[1]

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Crosses between commercial varieties of corn frequently have produced more in the F_1 generation than the average yield of the parents and in many cases more than the higher yielding parent. This suggests that varieties frequently may be too homozygous to permit maximum yields. Such a condition might be caused by an accidental narrowing of hereditary lines through the use of too few individuals for seed from time to time. It also might be caused, theoretically, at least, by close selection to a particular type; that is, close selection for certain superficial characters would affect productiveness if the genetic factors controlling such characters also affected the growth of the plant or happened to be linked with factors that did affect plant growth.

OBJECT OF THE INVESTIGATION

The object of the investigation was (1) to determine to what extent and in what length of time strains having distinct characteristics could be obtained by mass selection from a well-established variety of corn and (2) to determine the relative productiveness of the selected strains, of the F_1 crosses between them, and of the original variety.

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[1] The selection of the strains used in these experiments was begun under the direction of E. B. Brown, formerly Agronomist in the Office of Cereal Investigations, and was continued under his supervision through 1921. Most of the selections and records were made by him and by J. M. Hammerly, Assistant in Corn Investigations, Office of Cereal Investigations, during the earlier years and by the senior writer in the later years of the experiments.

MATERIAL AND METHODS

A strain of Boone County White, Cereal Investigations (C. I.) No. 119, was used in the investigation. This previously had been selected for productiveness by the ear-to-row method for about 15 years. Only sound well-formed ears were taken for seed during this time, but little effort was made to have the seed ears uniform as to particular characters. At the beginning of the present investigation the ears of C. I. No. 119 varied from smooth with almost flinty kernels to very rough with pinched-dented kernels, but they were not as rough as in many strains of Boone County White.

ESTABLISHING THE STRAINS

Selection of five strains was begun in 1915, a sixth strain being added in 1919. The basis of selection was as follows:

Strain No. 1.—Rough ears, 8 inches or more long, with 20 or more rows of pinched-dented kernels.

Strain No. 2.—Rough ears, 8 inches or more long, with 16 rows of crease-dented to pinched-dented kernels.

Strain No. 3.—Smooth ears, 10 inches or more long, 20 or more rows of dimple-dented to slightly crease-dented kernels.

Strain No. 4.—Smooth ears, 10 inches or more long, with 14 rows of dimple-dented kernels.

Strain No. 5.—Smooth ears, 10 inches or more long, with 12 rows of dimple-dented kernels.

Strain No. 6.—Smooth ears, any length, with 8 rows of dimple-dented kernels. This strain originated from a few 8-rowed ears found among those in strains Nos. 4 and 5 in 1918.

All the strains were grown in the vicinity of Washington, D. C., on essentially the same kind of soil. The mixed seed from 50 or more typical ears of a strain was planted in a field or plat. These plats were isolated as much as possible from each other and from other corn. Seed for the succeeding year was taken from only the interior rows when the plats were not completely isolated.

During the period of selection, 1,000 ears of each strain were classified on the basis of the number of kernel rows. These data are shown in connection with those from a similar classification of the ears from the yield comparison conducted in 1923.

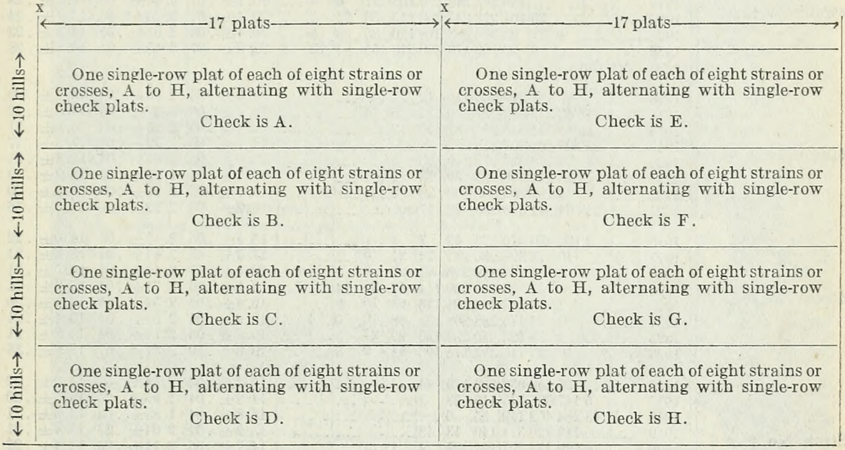
GROWING SEED FOR COMPARISON

All of the seed planted in the 1923 experiments was grown in 1922. Strains Nos. 2 and 4 were grown on private farms near Washington, and the other strains, including the original C. I. No. 119, were grown in isolated plats at the Arlington Experiment Farm, Rosslyn, Va. Crosses were obtained by growing plants of the different strains in each of these plats and detasseling. All sound ears of the crosses were used in the experiment, without reference to the number of rows or indentation of their kernels.

METHOD OF COMPARISON

The productiveness of the different lots of seed was compared at the Arlington Experiment Farm in 1923. The soil was a uniformly productive silt loam that had been pumped onto a low area in dredging out the channel of the Potomac River. The corn was planted in hills 3.3 feet apart each way. Excess seeds were planted, and the plat was thinned to an almost perfect stand of two plants per hill when the seedlings were about 8 inches high. The climate was extremely favorable for corn production, and excellent yields were obtained, C. I. No. 119 averaging 87.5 bushels of air-dry shelled corn per acre.

The method of comparison was an extension of the plan that has been described[2] for having the check plats constitute replications of the different sorts to be compared. The 21 kinds of seed, exclusive of C. I. No. 119, were divided into three groups, and C. I. No. 119 was added to each group. The eight lots in a group were compared in a single section. The rows were 10 hills long. A single row of each of the eight kinds alternating with single-row check plats constituted a unit which was replicated eight times. Each of the eight kinds of seed was used as the check in one replication. Thus, in section 1, C. I. No. 119 was the check in the first replication, strains Nos. 1, 2, 3, 4, 5, and 6, respectively, were the checks in the second to seventh replications, and the cross of strain No. 4 × strain No. 5 was the check in the eighth replication. This provided 17 plats of each strain or cross. Eight extra plats of C. I. No. 119 were grown in each section for additional checks. As these were comparable with the other plats in every way, the data on C. I. No. 119 are based on 25 replications in each section. A diagram of the arrangement in a section is shown in Figure 1.



One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is A.	One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is E.
One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is B.	One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is F.
One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is C.	One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is G.
One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is D.	One single-row plat of each of eight strains or crosses, A to H, alternating with single-row check plats. Check is H.

FIG. 1.—Diagram of the planting arrangement of a section in the comparisons at Arlington Experiment Farm in 1923. Eight lots were compared in each of three such sections. Extra rows of C. I. No. 119 are indicated by x

EXPERIMENTAL DATA

No data were obtained on the length of ears or the indentation of kernels, although these characters were considered in selecting seed. In general it may be said that strains Nos. 1 and 2 produced larger percentages of very rough ears and that strains Nos. 3, 4, 5, and 6 produced larger percentages of smoother ears in the later generations. Moreover, it became increasingly difficult to obtain seed ears of strain No. 1 that were up to the standard length of 8 inches, whereas this difficulty did not occur in the other strains. A representative seed ear of each of the strains except No. 6 is shown in Plate I. An ear of strain No. 6 and some extreme ears found among the other strains are shown in Plate II. Actual data showing the efficiency of selection are confined to the number of kernel rows on the ears.

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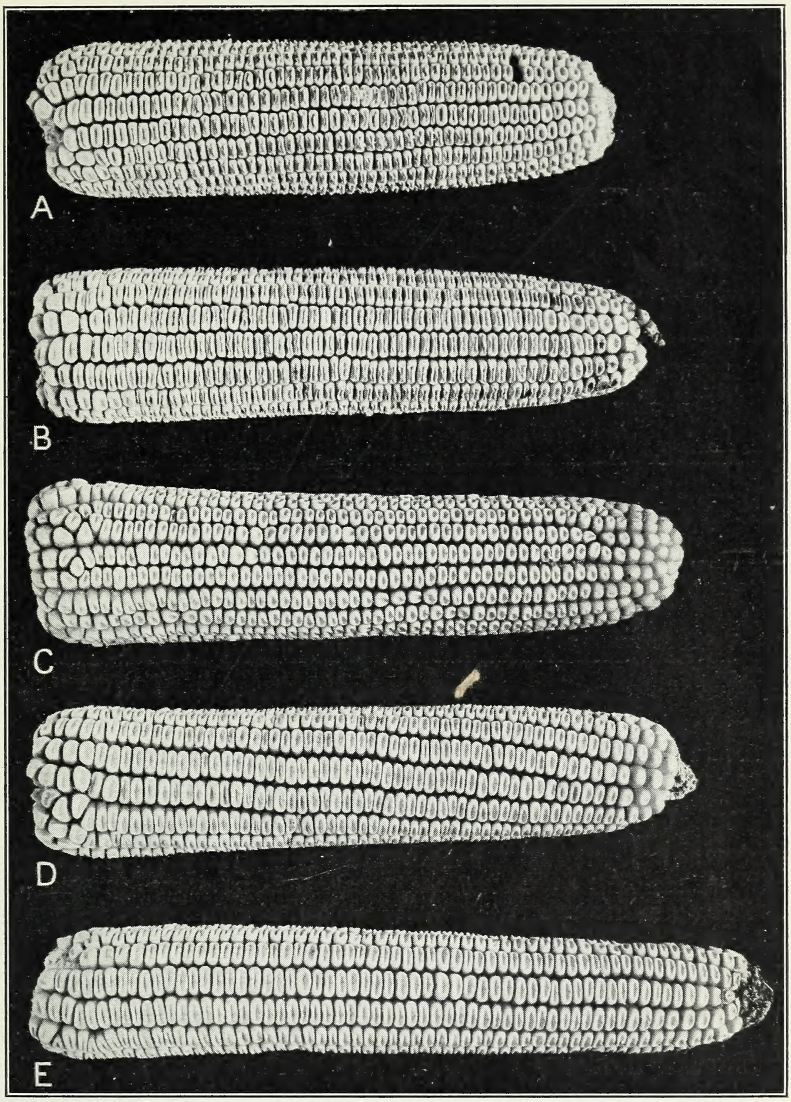
[2] Richey, F. D. Adjusting yields to their regression on a moving average as a means of correcting for soil heterogeneity. *In* Jour. Agr. Research, vol. 27, pp. 79–90, illus. 1924.

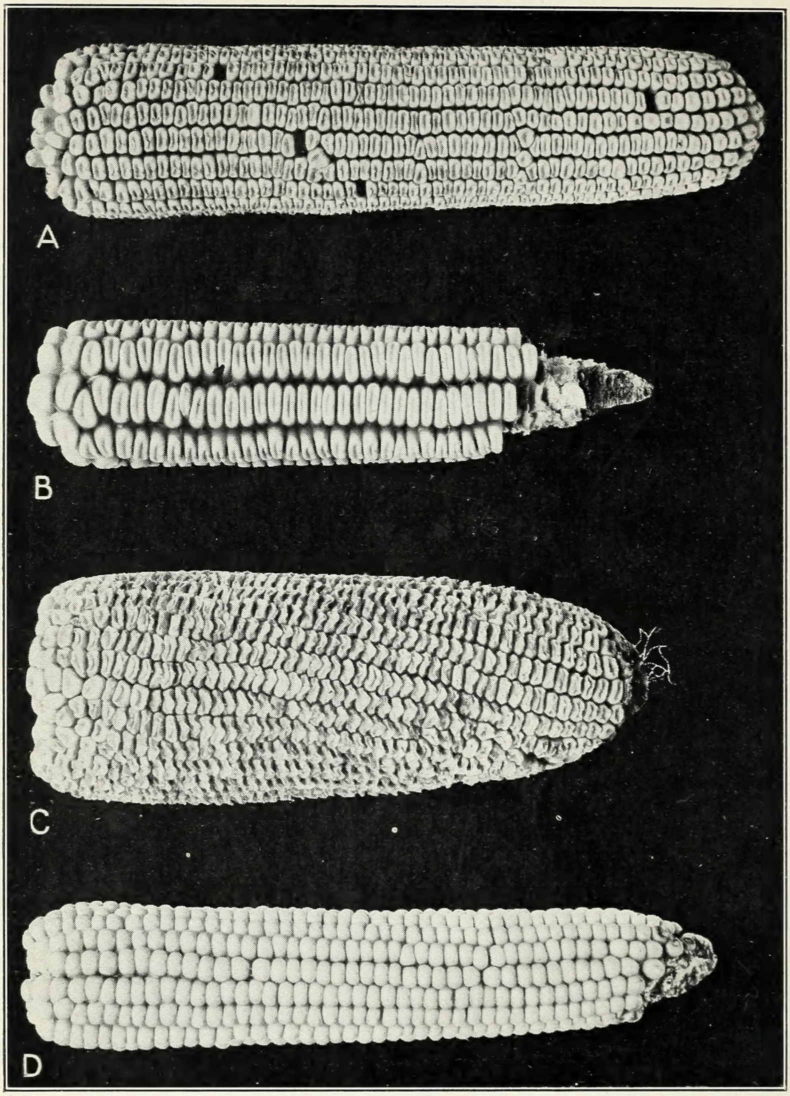
TABLE 1.—*Distribution of ears of C. I. No. 119 corn and six strains selected from it on the basis of number of kernel rows*

Strain or cross	Year	Number of ears per 1,000 by kernel-row classes													Mean number of kernel rows	Standard deviation	Coefficient of variation
		8	10	12	14	16	18	20	22	24	26	28	30	32			
C. I. No. 119	1923	---	2	55	279	353	219	76	15	1	---	---	---	---	16. 1±0. 04	2. 18±0. 03	13. 5±0. 17
Strain No. 1	1916	---	---	19	96	254	299	201	84	46	---	---	---	---	18. 0± . 06	2. 65± . 04	14. 7± . 23
	1917	---	---	4	42	239	295	248	116	48	9	---	---	---	18. 7± . 05	2. 55± . 04	13. 6± . 21
	1918	---	---	3	52	178	308	270	133	37	15	3	1	---	18. 9± . 06	2. 61± . 04	13. 8± . 21
	1919	---	---	---	---	135	284	243	176	108	27	0	27	---	20. 1± . 07	3. 06± . 05	15. 2± . 23
	1920	---	---	---	29	101	222	247	200	115	58	20	7	1	20. 4± . 07	3. 20± . 05	15. 7± . 24
	1921	---	---	4	21	93	200	283	218	120	35	20	6	---	20. 4± . 06	3. 01± . 05	14. 8± . 23
	1922	---	---	---	6	26	100	173	200	216	155	84	32	8	22. 9± . 07	3. 45± . 05	15. 1± . 23
	1923	[No data.]															
Strain No. 2	1916	---	---	42	163	307	303	115	42	27	---	---	---	---	17. 0± . 06	2. 56± . 04	15. 1± . 23
	1917	---	4	42	245	332	257	89	22	5	4	---	---	---	16. 4± . 05	2. 37± . 04	14. 5± . 22
	1918	---	2	48	245	345	251	82	25	2	---	---	---	---	16. 3± . 05	2. 25± . 03	13. 8± . 21
	1919	---	---	208	198	267	218	69	39	---	---	---	---	---	15. 7± . 06	2. 72± . 04	17. 3± . 27
	1920	---	1	33	178	327	273	149	33	5	---	---	---	---	16. 9± . 05	2. 34± . 04	13. 8± . 21
	1921	---	---	46	211	448	221	59	13	2	---	---	---	---	16. 2± . 04	1. 99± . 03	12. 3± . 19
	1922	---	---	33	182	365	285	100	33	2	---	---	---	---	16. 7± . 05	2. 20± . 03	13. 2± . 20
	1923	---	---	61	241	353	236	92	17	---	---	---	---	---	16. 2± . 08	2. 22± . 06	13. 7± . 36
Strain No. 3	1916	---	2	102	359	310	173	43	7	4	---	---	---	---	15. 5± . 05	2. 17± . 03	14. 0± . 22
	1917	---	---	10	78	328	255	231	74	21	3	---	---	---	17. 9± . 05	2. 44± . 04	13. 6± . 21
	1918	---	---	8	81	243	339	218	81	20	6	1	---	---	18. 1± . 05	2. 44± . 04	13. 5± . 21
	1919	---	---	---	57	57	343	329	114	57	28	14	---	---	19. 5± . 06	2. 71± . 04	13. 9± . 21
	1920	---	---	1	17	143	302	301	146	68	16	6	---	---	19. 4± . 05	2. 54± . 04	13. 1± . 20
	1921	---	---	3	24	173	288	288	138	68	16	0	1	---	19. 2± . 06	2. 58± . 04	13. 4± . 21
	1922	---	---	1	29	122	240	293	193	92	27	3	1	---	19. 8± . 06	2. 74± . 04	13. 8± . 21
	1923	---	---	9	25	118	281	275	190	84	9	9	---	---	19. 6± . 10	2. 71± . 07	13. 8± . 38
Strain No. 4	1916	---	---	26	150	332	256	179	44	14	---	---	---	---	17. 2± . 05	2. 44± . 04	14. 2± . 22
	1917	---	5	147	396	313	115	23	1	---	---	---	---	---	14. 9± . 04	1. 95± . 03	13. 1± . 20
	1918	1	43	284	462	149	55	6	---	---	---	---	---	---	13. 8± . 04	1. 88± . 03	13. 6± . 21
	1919	---	---	143	320	371	140	13	13	---	---	---	---	---	15. 2± . 04	2. 04± . 03	13. 4± . 21
	1920	---	16	189	374	291	102	23	4	1	---	---	---	---	14. 7± . 05	2. 11± . 03	14. 4± . 22
	1921	3	38	270	436	205	42	6	---	---	---	---	---	---	13. 9± . 04	1. 87± . 03	13. 5± . 21
	1922	---	7	163	419	281	107	21	2	---	---	---	---	---	14. 8± . 04	1. 97± . 03	13. 3± . 20
	1923	6	14	219	406	273	57	23	3	---	---	---	---	---	14. 4± . 07	2. 04± . 05	14. 2± . 37
Strain No. 5	1916	---	---	108	249	370	183	76	12	2	---	---	---	---	15. 8± . 05	2. 28± . 04	14. 4± . 22
	1917	3	31	216	413	236	85	14	2	---	---	---	---	---	14. 3± . 04	2. 07± . 03	14. 5± . 22
	1918	3	82	342	421	124	28	2	---	---	---	---	---	---	13. 3± . 04	1. 83± . 03	13. 8± . 21
	1919	---	58	395	419	104	11	11	---	---	---	---	---	---	13. 3± . 04	1. 73± . 03	13. 0± . 20
	1920	2	67	261	370	200	72	19	7	2	---	---	---	---	14. 1± . 05	2. 34± . 04	16. 6± . 26
	1921	---	72	481	290	115	39	---	---	---	---	---	---	---	13. 1± . 04	1. 85± . 03	14. 1± . 22
	1922	9	158	424	339	64	3	---	---	---	---	---	---	---	12. 6± . 04	1. 71± . 03	13. 6± . 21
	1923	5	44	475	359	95	22	---	---	---	---	---	---	---	13. 1± . 06	1. 66± . 04	12. 7± . 32
Strain No. 6	1920	20	156	478	294	36	14	---	---	---	---	---	---	---	12. 4± . 04	1. 74± . 03	14. 0± . 22
	1921	93	426	377	95	6	2	1	---	---	---	---	---	---	11. 0± . 04	1. 68± . 03	15. 3± . 24
	1922	132	360	440	65	3	---	---	---	---	---	---	---	---	10. 9± . 04	1. 62± . 03	14. 9± . 23
	1923	258	450	254	27	9	2	---	---	---	---	---	---	---	10. 2± . 05	1. 70± . 04	16. 7± . 39
No. 1 × No. 2	1923	---	---	---	30	116	268	291	156	99	36	3	---	---	19. 8± . 11	2. 77± . 08	14. 0± . 39
No. 1 × No. 3	1923	---	---	---	3	54	154	250	257	173	61	32	16	---	21. 4± . 12	3. 02± . 08	14. 1± . 39
No. 1 × No. 4	1923	---	---	18	147	358	245	174	43	12	0	0	3	---	17. 2± . 09	2. 46± . 06	14. 3± . 39
No. 1 × No. 5	1923	---	3	3	131	276	294	163	65	29	29	3	3	---	17. 9± . 11	2. 97± . 08	16. 6± . 44
No. 1 × No. 6	1923	---	---	75	290	250	168	104	58	46	6	3	---	---	16. 7± . 12	3. 21± . 08	19. 2± . 51
No. 2 × No. 1	1923	---	---	12	49	212	276	264	104	68	15	---	---	---	18. 8± . 10	2. 75± . 07	14. 6± . 39
No. 2 × No. 3	1923	---	---	6	143	254	338	158	65	34	3	---	---	---	17. 7± . 10	2. 55± . 07	14. 4± . 39
No. 3 × No. 1	1923	---	---	---	3	39	196	238	273	186	61	6	---	---	21. 1± . 10	2. 62± . 07	12. 4± . 34
No. 3 × No. 2	1923	---	---	9	133	286	342	159	56	12	0	0	0	3	17. 5± . 09	2. 43± . 06	13. 9± . 37
No. 3 × No. 4	1923	---	---	50	197	349	265	100	28	12	---	---	---	---	16. 6± . 09	2. 38± . 06	14. 3± . 39
No. 3 × No. 5	1923	---	---	44	250	317	250	111	17	9	3	---	---	---	16. 5± . 09	2. 40± . 06	14. 6± . 38
No. 3 × No. 6	1923	---	14	201	362	241	115	57	11	---	---	---	---	---	14. 9± . 09	2. 40± . 06	16. 1± . 42
No. 4 × No. 5	1923	3	45	307	435	179	28	3	---	---	---	---	---	---	13. 7± . 06	1. 80± . 05	13. 1± . 34
No. 6 × No. 1	1923	6	14	181	424	285	84	6	---	---	---	---	---	---	14. 5± . 07	1. 90± . 05	13. 1± . 34
No. 6 × No. 3	1923	---	45	354	443	105	53	---	---	---	---	---	---	---	13. 5± . 06	1. 79± . 04	13. 3± . 33



REPRESENTATIVE SEED EARS OF THE DIFFERENT STRAINS OF CORN

A, Strain No. 1; B, strain No. 2; C, strain No. 3; D, strain No. 4; E, strain No. 5



DIFFERENT KINDS OF EARS OF CORN OBTAINED DURING THE EXPERIMENTS

A, A 12-inch ear of C. I. No. 119; B, an ear of strain No. 6; C, an extreme ear of strain No. 1; D, an ear of the flint type

DATA ON NUMBER OF KERNEL ROWS

Data prior to 1923 were based on 1,000 ears of each kind grown in the seed plats. The data for 1923 were based on the ears produced in the yield comparison. About 340 ears of each strain and cross were available except in strain No. 1, some of the ears of which became mixed with other corn before counting. Ears that could not be classified definitely because of irregularity were included in the counts, but the distributions shown here are for ears per 1,000 classifiable ears. The slight discrepancies in the totals arise from rounding off decimals. The data showing the number of ears with different numbers of kernel rows, the mean, the standard deviation, and the coefficient of variation for each strain and cross throughout the experiment are shown in Table 1.

No data are available regarding the number of kernel rows on the ears of C. I. No. 119 at the beginning of the experiment. The 621 ears used to plant the ear-row plats from 1907 to 1918, inclusive, had an average of 16.6±0.05 kernel rows,[3] and the mean for the 1,475 ears of the 1923 crop was 16.1±0.04. Beginning with about 16.0 to 16.5, therefore, the mean number of kernel rows was shifted upward or downward by selection, so that the means ranged from 22.9±0.07 for strain No. 1 to 10.9±0.04 for strain No. 6 in the crop of 1922. This is a spread of 12 rows, or only 2 rows less than that of the entire distribution of C. I. No. 119 in 1923.

The seed planted to represent the different strains in 1923 was not selected for number of rows. Consequently the general tendency of the distributions in 1923 to approximate those in 1922 affords some indication of the degree to which the characteristic number of rows was fixed in the different strains. The standard deviations and coefficients of variation, in connection with the means, give a better measure of conformity to the characteristic number of rows. Because of the large influence of the means on the coefficients of variation and the slightly greater variation to be expected in strains with larger row numbers, both constants should be considered together. On this basis each of the strains, except perhaps No. 1, was practically as uniform by 1923 as a standard variety of corn, C. I. No. 119.

The numbers of kernel rows on the ears from the crosses were intermediate, in general, between those of the two parents. The distributions of the ears of three crosses and their parent strains are shown graphically in Figure 2.

There are some interesting differences in the distributions for the reciprocal crosses between strains Nos. 1 and 2, 1 and 6, and 3 and 6 (Table 1). In each case the distribution of the ears of the cross tends to be more like that of the pistillate parent strain. The difference of 2.2±0.08 rows in the reciprocal crosses between strains Nos. 1 and 6 is particularly striking. Whether this was due to some influence of the methods used or to inherent tendencies can not be determined. In view of the facts that the pollinations were not strictly controlled by bagging, etc., and that the seed ears used to represent the different sorts were not selected, too much importance probably should not be attached to this difference.

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[3] Richey, F. D., and Willier, J. G. A statistical study of the relation between seed-ear characters and productiveness in corn. U. S. Dept. Agr. Bul. 1321, 20 p. 1925.

DATA ON PRODUCTIVENESS

A summary of the yield data is shown in Table 2. The data in column 2 of this table show the total number of plants from which the yields were determined. The differences between the numbers of plants of any two kinds were negligible, and no corrections were made for stand. The data on shrinkage after harvest and percentage of grain to ear were determined from duplicate samples, each consisting of the entire product of a single replicate. The greater loss of moisture (column 3) in the selected strains with larger numbers of kernel rows probably was due to their slower drying between maturity and harvest. At least there was no evident difference in the maturity of the strains or crosses in the field. The selected strains with larger numbers of kernel rows had a higher percentage of grain (column 4) than those with fewer rows, as would be expected. There is no apparent reason for the low percentage of grain in strain No. 3. The relation between number of kernel rows and shrinkage or percentage of grain is less definite in the crosses between strains. The yield data (column 5) are the harvest weights computed to terms of air-dry shelled grain on the basis of the data in columns 3 and 4. The probable errors were computed from the formula—

$$\text{Error mean} = \pm 0.6745 \frac{\sigma}{\sqrt{n}}$$

n being 17 except for C. I. No. 119, where it was 25. The data in column 6 were obtained by dividing the values in column 5 by the mean yield of C. I. No. 119 in the same section.

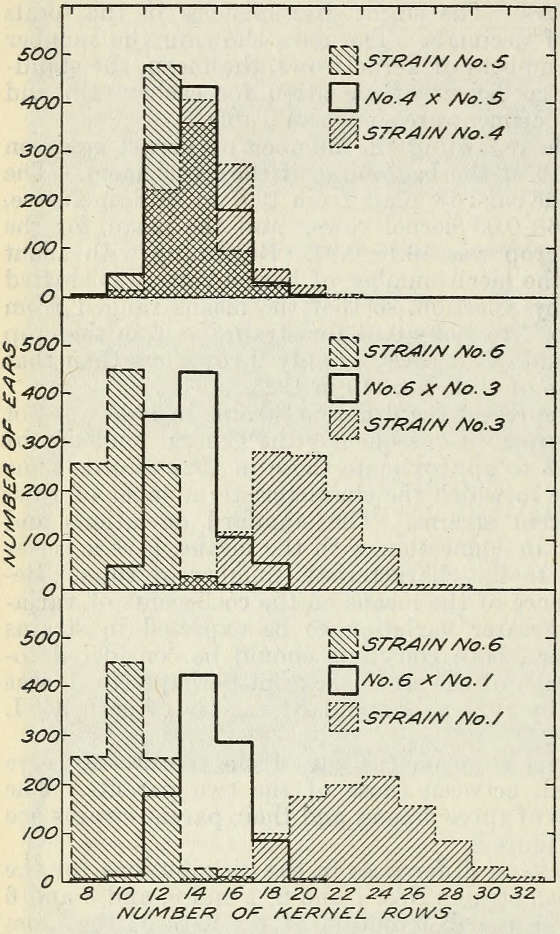

FIG. 2.—Distributions of the ears of three corn crosses and their parent strains with respect to the number of kernel rows

In order to determine whether any strain was grown on consistently better soil than the average, the yield of each plat was computed as a percentage of the average yield of the kind grown in that plat. A five-row moving average of these percentage yields then was computed, as described in a previous paper.[4] The means of the values so obtained for all of the plats of each strain or cross are shown in column 7 of Table 2. These values afford another measure of the reliability of the comparisons, as they indicate the relative productiveness of the soil on which the different lots were grown.

TABLE 2.—*Yields of grain of C. I. No. 119, of six strains of corn selected from it, and of crosses between these strains obtained in 1923*

Strain or cross designation	Total number of plants	Shrinkage in drying	Grain	Average yield of air-dry shelled grain		Mean of 5-row moving average
				Per row	Ratio to C. I. No. 119	
1	2	3	4	5	6	7
		Per cent	*Per cent*	*Pounds*	*Per cent*	*Per cent*
Section 1:						
C. I. No. 119	491	28.5	83.1	12.3±0.15	100.0±0.12	101
No. 1	329	33.1	83.2	10.8± .15	87.5± .12	100
No. 3	329	28.8	80.1	10.5± .14	85.7± .12	98
No. 2	328	29.8	83.6	11.1± .08	90.3± .06	99
No. 4	331	28.6	83.1	11.3± .16	91.6± .13	100
No. 5	329	25.4	82.0	10.8± .11	87.5± .09	99
No. 6	334	26.0	81.8	10.9± .12	88.3± .10	99
No. 4×No. 5	333	25.7	82.5	11.9± .10	96.7± .08	101
Section 2:						
C. I. No. 119	489	28.5	83.1	12.1± .12	100.0± .10	101
No. 1×No. 2	330	28.7	83.6	11.5± .16	95.2± .13	99
No. 1×No. 3	329	32.1	82.4	10.9± .16	90.6± .13	98
No. 1×No. 4	332	29.7	82.9	11.6± .19	96.3± .16	100
No. 1×No. 5	328	33.0	83.3	11.5± .15	95.2± .12	100
No. 1×No. 6	335	31.0	83.8	11.6± .12	96.0± .10	100
No. 2×No. 1	333	30.4	84.0	11.7± .15	96.6± .13	100
No. 2×No. 3	330	29.9	83.2	11.1± .16	92.2± .13	99
Section 3:						
C. I. No. 119	488	28.5	83.1	12.0± .14	100.0± .12	101
No. 3×No. 1	331	33.6	79.0	10.2± .14	85.5± .12	100
No. 3×No. 2	334	29.5	84.0	10.9± .13	90.7± .11	99
No. 3×No. 4	331	27.5	83.3	11.0± .10	91.9± .08	100
No. 3×No. 5	338	27.6	82.5	12.4± .13	103.5± .11	102
No. 3×No. 6	338	26.8	81.5	11.9± .15	99.7± .12	99
No. 6×No. 1	337	30.2	82.7	12.5± .12	104.5± .10	100
No. 6×No. 3	339	26.8	82.5	12.6± .12	105.7± .10	99

DISCUSSION

Without regard to the reason, it is evident that close selection to any type, as practiced in these experiments, resulted in decreased productiveness. The most productive strain, No. 4, the 14-rowed smooth selection, yielded 8.4±0.20 per cent less than C. I. No. 119 and the least productive, No. 3, the 20-rowed smooth selection, 14.3±0.19 per cent less. The 14-rowed smooth and 16-rowed rough selections, Nos. 4 and 2, were more productive and also departed less from the characteristic condition of the parent variety than the others. If the difference in the productivity of the plats on which the strains were grown, as indicated by the data in Table 2 (column 7), is taken into account, the selections for 8-rowed and 12-rowed ears, Nos. 6 and 5, were more productive than the two selections for

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[4] Richey, F. D. Op. cit.

20-rowed ears, Nos. 1 and 3. The difference is not large, however, and the outstanding fact is the reduced yield of all the selected strains.

Three of the fifteen crosses yielded more than C. I. No. 119, and a fourth, No. 3×No. 6, probably was more productive. The other 11 crosses all yielded significantly less than C. I. No. 119. Only one cross, No. 3×No. 1, yielded less than the better parent, and it yielded less than the poorer parent. There is a tendency for the crosses with a lower mean value for number of kernel rows to be more productive. These crosses also are between strains differing more with respect to number of rows.

The mean values for number of kernel rows and for the relative productiveness of the crosses and their parent strains have been brought together in Table 3, where the crosses are arranged in the order of increasing differences between the number of kernel rows on the ears of the parent strains. These fall into three more or less natural groups, those in which the parents differed (1) by less than 4 rows, (2) by 4 to 8 rows, and (3) by 8 to 12 rows. The average productiveness of the crosses in these groups is 91.1, 96.7, and 100.2 per cent, respectively.

Table 3.—*Summary of data showing the relations between numbers of kernel rows and productiveness in six selected strains of corn and of crosses between them*

Parent strains		Average number of kernel rows on ears					Relative productiveness as compared to C. I. No. 119 (per cent)			
		Parent strains				Cross	Parent strains			Cross
♀	♂	♀	♂	Average	Difference		♀	♂	Average	
No. 4	No. 5	14.4	13.1	13.8	1.3	13.7	91.6	87.5	89.6	96.7
No. 1	No. 3	22.0	19.6	20.8	2.4	21.4	87.5	85.7	86.6	90.6
No. 3	No. 1	19.6	22.0	20.8	2.4	21.1	85.7	87.5	86.6	85.5
No. 2	No. 3	16.2	19.6	17.9	3.4	17.7	90.3	85.7	88.0	92.2
No. 3	No. 2	19.6	16.2	17.9	3.4	17.5	85.7	90.3	88.0	90.7
No. 3	No. 4	19.6	14.4	17.0	5.2	16.6	85.7	91.6	88.7	91.9
No. 2	No. 1	16.2	22.0	19.1	5.8	18.8	90.3	87.5	88.9	96.6
No. 1	No. 2	22.0	16.2	19.1	5.8	19.8	87.5	90.3	88.9	95.2
No. 3	No. 5	19.6	13.1	16.4	6.5	16.5	85.7	87.5	86.6	103.5
No. 1	No. 4	22.0	14.4	18.2	7.6	17.2	87.5	91.6	89.6	96.3
No. 1	No. 5	22.0	13.1	17.6	8.9	17.9	87.5	87.5	87.5	95.2
No. 3	No. 6	19.6	10.2	14.9	9.4	14.9	85.7	88.3	87.0	99.7
No. 6	No. 3	10.2	19.6	14.9	9.4	13.5	88.3	85.7	87.0	105.7
No. 1	No. 6	22.0	10.2	16.1	11.8	16.7	87.5	88.3	87.9	96.0
No. 6	No. 1	10.2	22.0	16.1	11.8	14.5	88.3	87.5	87.9	104.5

The coefficient of correlation for productiveness of the crosses with the difference between the numbers of kernel rows in the two parent strains, as determined from the ungrouped data, is 0.67±0.10. The correlation between the mean numbers of rows of the crosses and their productiveness is −0.78±0.07. Because of the way the strains were combined a large difference between the parents necessitates a lower average number of rows in the cross. There was no important relation between the number of rows and productiveness in the parent strains. Consequently it seems likely that the difference between the parental numbers was the more important factor influencing yield and that most of the relation indicated by

—0.78 was due to the negative correlation between the number of rows in a cross and the difference between the numbers in its parents.

There is little reason to suppose that selection for number of kernel rows should result in decreased productiveness in every case unless all of the selected strains possessed something in common. The wide range of row numbers used in these experiments, extending well to each side of the mean of the parent variety, seems to preclude number of rows, as such, from being the determining factor. The reduction in yield accompanying close breeding in corn is well recognized. There is little reason to suppose, however, that close breeding in the ordinary sense has taken place in any of the strains with the possible exception of No. 6. This strain may have originated from the four 8-rowed ears recorded in strains Nos. 4 and 5 in the crop of 1918. Not less and usually more than 50 ears were used to represent each of the other strains each year. It seems probable that this number of open-pollinated ears taken at random should include enough germinal heterogeneity to satisfy the requirements even of corn. If so, conditions similar to those following actual close breeding have been due to the selection.

Much of the detailed evidence in favor of the present view that hybrid vigor is due to the complementary action of dominant favorable growth factors was obtained from inbreeding experiments with corn. In those experiments a homozygous condition for many factors was obtained automatically by self-fertilization. A decrease in vigor and productiveness accompanied the approach to a homozygous condition, and crossing unrelated inbred lines restored a heterozygous condition and yield.

A standard variety of long standing was used in the present experiments. Strains differing markedly in certain characteristics were obtained from this variety by mass selection without inbreeding. Presumably each of these strains became more or less homozygous for the combination of genetic factors determining its characteristic number of kernel rows. Crossing unlike strains would produce a heterozygous condition among the factor pairs concerned, and there would be more factor pairs concerned in crosses between strains differing more widely. Under these conditions crosses between the more unlike strains would be heterozygous for more factor pairs and under the Mendelian interpretation of hybrid vigor would be more productive. The observed facts are in reasonable accord with this hypothesis, and the experiments afford further evidence in favor of this interpretation of hybrid vigor.

In their practical application the experiments indicate that a decrease in vigor and productiveness similar to that following inbreeding may result from too close selection for a particular kind of ear. Careful experiments have failed to demonstrate a marked consistent superiority for any specific kind of ear. Other experiments have shown that the yields of crosses between varieties of corn frequently are more productive than the average of the parents, thus indicating that the parent varieties are too homozygous to permit maximum yields. Just what constitutes too close selection is not known. In view of the lack of evidence in favor of any particular kind of ear and the abundant evidence of the decreased yields that follow close breeding, however, it seems best to stay on the safe side by avoiding such close selection. It probably is safer also to avoid close selection for any other characters unless they are known to be associated with productiveness. In any event, the emphasis that is placed upon uniformity of sample in corn shows seems unfortunate if it is to be taken as indicating the desirability of having a variety of corn with uniform ears.

SUMMARY

Six strains of corn differing in the number of kernel rows on the ears and the indentation of the kernels were isolated by mass selection from C. I. No. 119, a strain of Boone County White. The productiveness of these strains and of crosses between them was compared with that of the parent variety.

All of the selected strains yielded less than the parent variety. The strains which departed less from the characteristic condition of the parent variety with respect to number of kernel rows tended to be more productive than those that departed more from the characteristic condition of the parent variety.

The crosses between selected strains ranged from about 15 per cent less productive to about 5 per cent more productive than C. I. No. 119.

There was a direct relation between the productiveness of the individual crosses and the number of kernel rows by which their parent strains differed. This fact was interpreted as indicating that the selected strains were more or less homozygous for the different combinations of genetic factors determining the different numbers of kernel rows.

On this basis, close selection for a specific kind of ear would tend to bring about a homozygous condition of the factors necessary for that kind of ear, and decreased vigor and productiveness similar to that caused by inbreeding would follow.

In view of the lack of evidence of marked consistent superiority for any particular kind of ear, it is unfortunate to teach that uniformity among the ears of a variety of corn is desirable by attaching importance to uniformity of sample, as is done in corn shows.

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